Chapter 2
Scope of Investigations

2-1. Background

From project conception through construction and throughout the operation and maintenance phase, geotechnical investigations are designed to provide the level of information appropriate to the particular project development stage. In most instances, initial geotechnical investigations will be general and will cover broad geographic areas. As project development continues, geotechnical investigations become more detailed and cover smaller, more specific areas. For large, complex projects, the geotechnical investigation can involve highly detailed geologic mapping such as a rock surface for a structure foundation. The scope of the various increments of investigation are described in the following paragraphs. Although some material is presented in detail, rigid adherence to an inflexible program is not intended. It is the responsibility of the geotechnical personnel in the field operating activities to design individual geotechnical investigations to the particular project requirements and local conditions. However, there are minimum requirements for geotechnical investigations to be performed as part of the project development stages, and this manual serves to outline these basic standards. All geotechnical investigations should be planned and conducted by the district element having geotechnical design responsibility. No geotechnical investigation should be contracted out unless the district geotechnical design element reviews and approves the scope of work.

Section I
Civil Works Projects

2-2. Reconnaissance and Feasibility Studies

a. Purpose. Reconnaissance studies are made to determine whether a problem has a solution acceptable to local interests and is in accordance with administrative policy. If so, reconnaissance studies provide information to determine whether planning should proceed to the feasibility phase (ER 1110-2-1150). Feasibility studies identify and evaluate the merits and shortcomings of environmental, economic, and engineering aspects of the proposed project. Planning guidelines for conducting these studies are contained in ER 1105-2-100. Guidelines on engineering activities during feasibility and preconstruction planning and engineering studies are provided in the 1110 series of publications.

b. Scope of geotechnical investigations. Geotechnical investigations during planning studies should be designed to provide information at a level such that critical geotechnical features of candidate sites may be compared in the feasibility study report. These investigations should be sufficiently complete to permit selection of the most favorable site areas within the regional physical setting, determine the general type of structures best suited to the site conditions, evaluate the influence of hydrogeology on site design and construction, assess the geotechnical aspects of environmental impact, and to ascertain the costs of developing the various project plans in sufficient detail to allow comparative cost estimates to be developed.

c. Investigation steps. Planning-level geotechnical investigations are generally performed in two parts: development of regional geology and initial site investigations. The regional geology investigations are carried out during early stages of the study. Initial field investigations begin after the regional studies are sufficiently detailed to identify areas requiring geotechnical clarification.

(1) Development of regional geology. Figure 2-1 is a schematic diagram showing the steps involved and data needed to evaluate the regional geology of a site. Knowledge of the regional geology is essential to preliminary planning and selection of sites and to interpretation of subsurface exploration data. With the exception of fault evaluation studies, determination of seismicity and preliminary selection of the design earthquake are performed in conjunction with evaluation of the regional geology. Much of the data needed for describing the regional geology and for determining seismicity are identical, and therefore, the efforts can be combined. Engineering seismology requirements for more in-depth studies of tectonic history, historical earthquake activity, and location of possible active faults are a logical extension of the regional geologic studies. Requirements for conducting earthquake design and analyses, including geological and seismological studies, are contained in ER 1110-2-1806.

(a) Utilization of remote sensing information in assessing the regional geology of a site can greatly increase effectiveness and reduce time and costs. Commonly, a series of remote sensing images, taken at various times, are available for a site. Remote sensing images for evaluating regional geology generally include both aerial photographs and satellite images. Remote sensing analysis can be used to evaluate geomorphic characteristics and geologic structure; map soils, sediment sources, and transport directions; and monitor and evaluate environmental impacts. Use of remote sensing for geological investigations is discussed by Gupta (1991). Remote sensing applications in desert areas are discussed by Rinker et al. (1991). Principal sources of remote sensing imagery include the U.S. Geological Survey (USGS) at 605-594-6151 (or edcwww.cr.usgs/content_products.html on the computer Internet, or World Wide Web) and U.S. Department of Agricultural (USDA) Farm Security Agency at 801-975-3503.

(b) Compiled and properly interpreted regional geologic and field reconnaissance information should be used to formulate a geologic model for each site. The use of a Geographic Information System (GIS) is highly recommended for developing this model. A GIS provides a platform in which to digitally store, retrieve, and integrate diverse forms of geo-referenced data for analysis and display. A GIS can be thought of as a high-order map that has the capability of distilling information from two or more map layers (Star and Estes 1990; Environmental Systems Research Institute (ESRI) 1992). Application of GIS to geotechnical studies enhances data management with respect to project planning/design, field work strategy, map/statistical generation, and identification/correlation of important variables. The application of a GIS to a project depends on the size and complexity of the project and the availability of usable data. Judgement is needed to evaluate the benefits of a GIS versus the high cost of initial construction of the model. A project GIS can be used by all parties (e.g., designers, engineers, geologists, archaeologists) in all phases of a project from site selection to postconstruction operations and maintenance.

(c) Whether done using a GIS or more traditional methods, the geologic model will be revised during successive investigation stages and thereby provide the information necessary to determine the scope of initial field investigations. Procedural information on the steps required to develop the regional geology and perform field reconnaissances is contained in Chapter 3.

(2) Initial field investigations. Figure 2-2 details the general procedures for initial field investigations. Areal extent of the investigations is determined by the size and nature of the project. However, each site investigation should provide information on all critical geotechnical features that influence a site. Procedural information for conducting a surface field investigation is presented in Chapter 4, and for subsurface field investigations in Chapter 5. Major projects, such as dams and reservoirs, electric generating plants, and locks and dams, require comprehensive field investigations. Procedures for carrying out such detailed investigations are discussed in Chapter 6. Areal and site geotechnical mapping allow early modification of initial geologic models and tentative layouts for

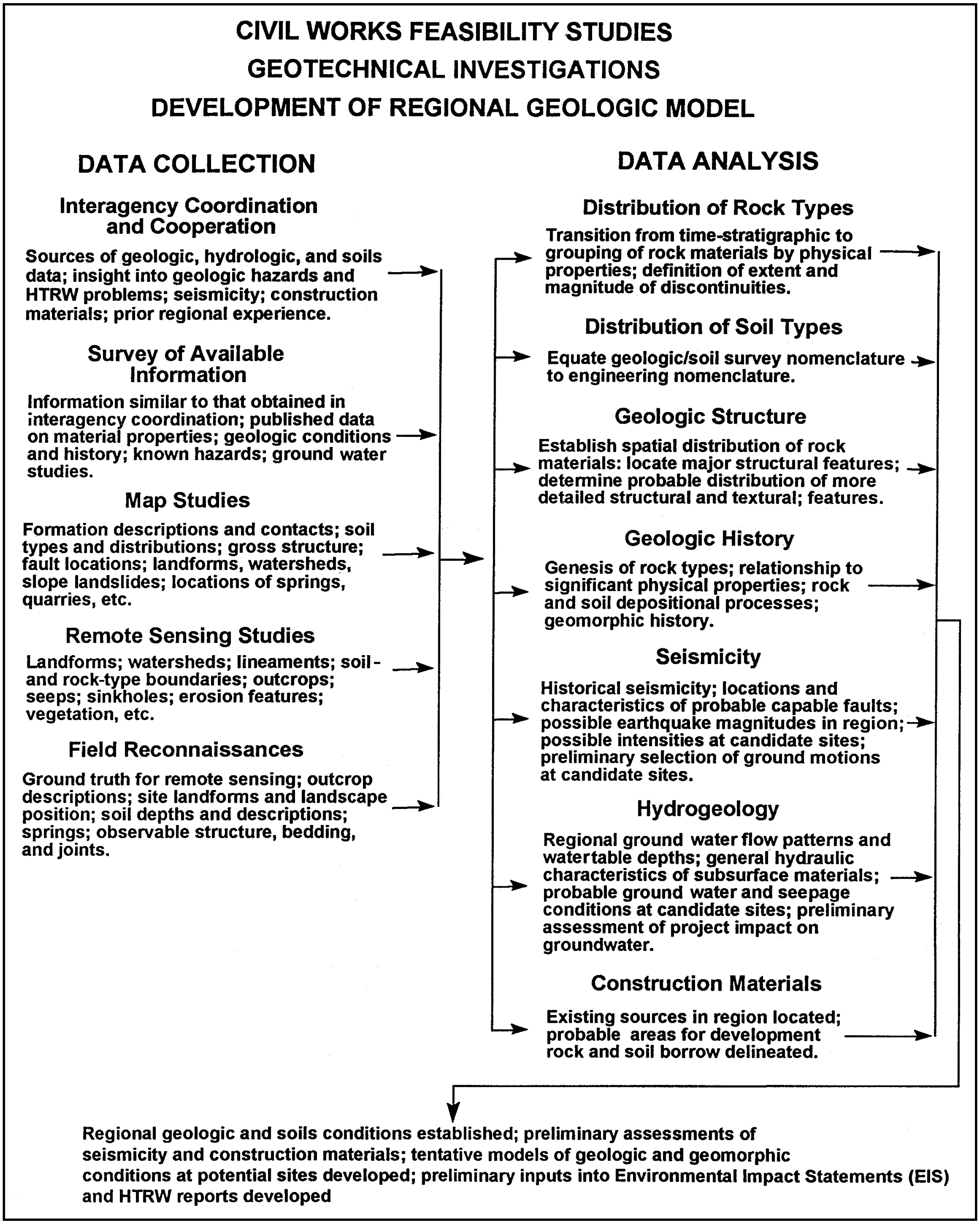

Figure 2-1. Schematic diagram of the development of regional geology

CIVIL WORKS FEASIBILITY STUDIES
GEOTECHNICAL INVESTIGATIONS

INITIAL FIELD INVESTIGATIONS

DATA COLLECTION

Areal and Site Geotechnical Mapping

Distribution of surface materials; structure; relation between materials and geomorphic expression; tentative locations for geophysical and/or subsurface explorations.

Surface Geophysical Surveys

Distribution of distinguishable subsurface materials at potential structure sites and rock and/or soil borrow areas; depth to water table; preliminary data on elastic and electrical properties; initial assessment of homogeneity of subsurface.

Subsurface Explorations

Control borings at potential structure sites and rock and/or soil borrow areas borehole logs; index tests on representative rock and soil samples; in situ hydraulic tests; camera or TV surveys; downhole geophysical logs.

DATA ANALYSIS

Aerial Conditions

Develop map of project area; describe possible material sources, material types, properties, amounts; determine unusual or safety related geologic conditions, faults, landslides, sinkholes, solution susceptible materials, etc.; update and expand hydrogeologic analyses including potential impacts on ground water.

Site Conditions

Correlate surface and subsurface data at potential sites; develop geologic map and sections for each site; assess structural and textural data for materials; assess results of index tests; develop preliminary assessment of rock and soil foundation conditions; delineate conditions affecting choice of structure for each site.

Geologic, soils, and engineering conditions evaluated to a level necessary to ensure each plan is a viable, safe, and complete technical system; geologic models at proposed sites upgraded; level of geotechnical investigations necessary to accomplish design established; need for dynamic analyses tentatively determined; EIS input updated.

Figure 2-2. Schematic diagram of initial field investigations surface geophysical surveys and subsurface explorations. Properly conducted surface geophysical surveys can provide information over relatively large areas on overburden depths, depth to the water table, and critical geologic contacts. Such surveys, prior to exploration drilling, can reduce the number of borings in proposed structure foundation areas and, in some cases, the number of borrow area borings. The surveys should be run along axes of potential dam sites and along canal alinement; at lock, off-channel spillways and tunnel and conduit sites; at potential borrow and quarry sites; and at locations where buried channels, caverns, or other elusive, but important, geologic conditions are suspected.

(a) Exploratory drilling is required at all sites to be included in the feasibility study. The numbers and depths of borings required to provide adequate coverage cannot be arbitrarily predetermined but should be sufficient to reasonably define the subsurface in the various site areas. Investigations necessary for levees, flood walls, pumping plants, recreation areas, and other miscellaneous structures are not as extensive as those required for major structures and projects. Generally, the scope of the regional geologic study is much reduced for projects authorized for site-specific reasons.

(b) The field investigation program should be tailored to site-specific needs. Field investigations in connection with planning of channel improvements or diversion channels should be sufficient to determine the types of materials to be excavated, hydraulic conductivity of the substrate, stability of bank slopes, and susceptibility of the substrate to scour. Assessment of channel stability for flood control projects is discussed in EM 1110-2-1418. In the case of irrigation or perched canals, seepage losses may be a significant problem. The field investigations should examine the need for an impervious lining and the availability of material for this purpose.

d. Reporting for feasibility studies. The reporting of results for feasibility in accordance with the overall study reporting requirements is contained in ER 1105-2-100. The results of all geotechnical investigations performed as part of the feasibility study efforts will be presented in detail. Sufficient relevant information on the regional and specific site geotechnical conditions must be presented to support the rationale for plan selection, project safety, environmental assessments including HTRW potential, and preliminary project design and cost estimates. This information should be presented in summary form in the feasibility report and in sufficient detail in appendices to allow evaluation and review.

(1) The feasibility report should contain summaries of the regional geology, soils, hydrogeology, and seismological conditions plus brief summaries of the areal and site geotechnical conditions for each detailed plan. These summaries should include local topography, geomorphic setting and history, thickness and engineering character of overburden soils, description of rock types, geologic structure, degree of rock weathering, local ground water conditions, possible reservoir rim problems, description of potential borrow areas and quarries, accessibility to sources of construction materials, and potential for HTRW sites. In addition, special foundation conditions such as excavation or dewatering problems, low-strength foundations, and cavernous foundation rock should be described. The summaries should conclude with a discussion of the relative geotechnical merits and drawbacks of each plan.

(2) Discussions of the regional geology and initial field investigations should be presented in an appendix on engineering investigations. The content of the discussion on regional geology should include the items outlined in Figure 2-1. In addition, a discussion of topography should be included. Drawings should be used to explain and augment the detailed discussion of regional geology. As a minimum, the drawings should include a regional geology map, regional geologic sections showing the spatial relationship of rock units and major geologic structures, a regional lineament map, and a map of recorded and observed seismic events (epicenter map). Dearman (1991) describes the principles of

engineering geologic mapping. Because summaries of areal and site geotechnical conditions for each detailed plan will be included in the feasibility report, the detailed discussion of areal and site geology, foundation conditions, and problems presented in the appendix may be limited to the recommended detailed plan. Figure 2-2 contains much of the information which should be included in the detailed discussion of areal and site geotechnical conditions. The discussion should indicate the sources from which information was obtained and will include the following items:

(a) Types of investigations performed.

(b) Areal and site geology (including topography of site or sites).

(c) Engineering characteristics of soil, rock, foundation, and reservoir conditions.

(d) Mineral deposits.

(e) Potential borrow and quarry sites.

(f) Available construction materials.

(g) Conclusions and recommendations.

(h) Graphics.

2-3. Preconstruction Engineering and Design Studies

a. Purpose. Preconstruction engineering and design (PED) studies are typically initiated after a feasibility study has been completed. PED studies are developed to reaffirm the basic planning decisions made in the feasibility study, establish or reformulate the scope of the project based on current criteria and costs, and formulate the design memoranda which will provide the basis for the preparation of plans and specifications. Figure 2-3 schematically outlines the engineering tasks for the PED studies with the requirements for geotechnical information.

b. Scope of geotechnical investigations. Geotechnical investigations performed during the PED studies should be in sufficient detail to assure that authorized measures can be implemented. The emphasis is toward site-specific studies which will provide the detail and depth of information necessary to select the most suitable site and structures to achieve project goals. The studies are performed in a series of incremental steps of increasing complexity beginning with the site selection study on major projects and continuing through feature design studies. Geotechnical procedures for performing field and laboratory investigations for these studies are found in Chapters 4 through 7.

c. Site selection study. This study serves to provide criteria for selecting the most appropriate site for the authorized project.

(1) Preliminary. The initial phase of the PED should begin with a comprehensive review of all geotechnical studies made during the feasibility study period. If there is a significant gap in time between the feasibility and PED studies, considerable geotechnical information may have been generated, compiled, analyzed, and published by Federal and State geotechnical agencies. These data should be obtained and correlated with the completed studies for evidence of significant changes in the geological knowledge of the study region. This is particularly important in the disciplines of seismology and hydrogeology.

CIVIL WORKS DESIGN MEMORANDUM STUDIES

GEOTECHNICAL INVESTIGATIONS

Purpose and Scope

Perform all engineering, design, and reporting for the authorized plan. Serve as a basis for preparation of constructions, plans, and specifications. Primarily concerned with the functional and technical design of structures necessary to achieve project objectives with the development of plans and specifications.

TASKS

- **Develop engineering details of approved project plan.**
- **Update cost and benefit estimates.**
- **Provide basis for cost-sharing agreements, prepare plans and specs, acquire lands, and negotiate relocation agreements.**
- **Establish design and operating requirements to ensure a safe functional project.**
- **Facilitate orderly scheduling and programming of funds for detailed design and construction.**
- **Continue environmental assessment based on required additional studies identified in the draft EIS.**
- **Provide basis for recommendations of the District Engineer.**

Sufficient geologic and soils information to verify project plan, axis selection, types of structures, estimates of costs, and to support the project purpose.

Field investigations, lab analyses, design computations, to determine adequacy and use of materials, strength, slopes, and protection of critical sections of embankments and foundations.

Foundation investigations, hydraulic design studies, and cofferdam design studies to determine most economical water control plan.

Field investigations, analyses, and views of owners of relocations.

Describe sources and indicate stability of concrete aggregate, cement, earth and rock borrow materials.

Investigations and laboratory analyses and typical design computations to determine source, adequacy, and use of construction materials

Develop plans for reading and evaluating instrument data and making visual inspections of dams and downstream areas, both related to pool level.

Determine necessary instrumentation.

Figure 2-3. Outline of preconstruction engineering and design studies

(2) Data collection. In the case of major projects such as dams, powerhouses, and navigation structures, some latitude normally exists in the proposed locations of the structures. At this stage, possible structure sites that would serve the intended project purposes should be evaluated before selecting a field investigations program. Geologic and hydraulic information collected during the feasibility study is generally sufficient for this purpose. After the obviously poor sites have been eliminated, a field investigation program should be developed. The type of data and collection methodology are outlined schematically in Figure 2-4. The investigation program should emphasize the completion of surface geologic mapping, expansion of surface geophysical surveys, detailed remote sensing analysis, and broadening of the scope of ground water investigations. Sufficient borings should be made at each potential site so that correlation of surface mapping and geophysical surveys is reasonably accurate. Use of the cone penetrometer and standard penetrometer test methods as part of a subsurface investigation program should be evaluated where geologic conditions are appropriate for these and subsequently more complex site studies. Subsurface sampling should be comprehensive to the point where laboratory indexing of engineering properties of soils and rock types, where appropriate, can be accomplished. Earthquake engineering analyses should be made if the seismicity studies made during the feasibility study indicate their need. At this time, a preliminary seismic evaluation should be made of the proposed structures and trenching performed if local active faulting is identified. The end result should be that areal and site geotechnical conditions are defined to the extent necessary to support design studies needed for reliable cost estimates. Data on proposed sites should be sufficiently complete to fully consider the effects of geotechnical conditions on site selection.

(3) Reporting site selection studies. The reporting of results of site selection studies will be in accordance with ER 1110-2-1150. The site selection design memorandum may be a separate document prepared prior to the PED for complex projects, or may be submitted as a major appendix to the PED. The content of the Site Selection Memorandum will include the items shown in Figure 2-4. Discussions will be augmented by geologic maps and profiles, boring logs, and laboratory and geophysical data all presented at a readable scale. The recommended site must be validated by sufficient geotechnical information in light of current conditions and criteria to avert reformulation of the project during the PED studies because of geotechnical problems.

d. Design investigations. Upon commencement of final design investigations, all previous engineering and design reports for the selected plan are carefully reviewed before initiating additional field investigations. These efforts provide information to support cost estimate decisions regarding the functional and technical design of structures necessary to achieve project objectives and development of construction plans and specifications. Design investigation tasks are outlined schematically in Figure 2-5 and are discussed in the following text.

(1) Preliminary. Upon commencement of the design investigations (postsite selection), all regional and site-specific geotechnical data should be reviewed before commencement of field investigations. New data, particularly that generated by other agencies, both Federal and state, should be obtained and incorporated into the original data base.

(2) Data collection. The foundation and design data collection activities are iterative, developing greater detail as the project design progresses toward the preparation of plans and specifications.

(a) PED data collection. In general, a closer order of subsurface investigations is then used in site selection studies. Where soils strongly influence the foundation design, undisturbed soil sampling should be initiated or expanded to classify and index their engineering properties in more comprehensive detail (Cernica 1993). Rock types and conditions, geologic structure, and engineering properties should

SITE SELECTION INVESTIGATION

DATA COLLECTION

Aerial and Site Geotechnical Mapping

Prepare area and site maps for each candidate site; distribution of surface materials; outcrop locations; rock structure; springs; slope conditions; potential hazards; determine boring and geophysical survey locations.

Groundwater Data

Review data: compile water-well and other piezometric data: determine needed additional data: start field collections.

Surface Geophysical Surveys

Subsurface material distribution at potential structure sites, quarry, and borrow areas; water table depths; data on electrical and elastic material properties. If needed, start special surveys (e.g., to obtain dynamic properties or void detection).

Subsurface Explorations

Borings at potential structure, quarry, and borrow areas; log soil and rock types, rock structure, and drilling conditions; water pressure or pumping tests; camera or TV surveys; in-hole geophysical surveys for correlation and, where needed, special properties.

Material Testing

Classification and index tests on foundation, quarry, and borrow materials; preliminary special tests where needed (e.g., for dynamic analysis).

Trenching

If and where needed to evaluate fault activity.

DATA ANALYSIS

Area Conditions

Compile geologic maps of project areas; show all pertinent geologic and soils conditions (e.g., landslides, sinkholes, potential reservoir leakage locations, etc.); develop geologic profiles; locate mineral resources.

Site Conditions

Compile detailed geology maps for each site; develop geologic sections; classify soils; describe rock types; show rock structure and fracturing; describe ground-water conditions and hydraulic properties of subsurface materials; describe rock weathering; assess test results, discuss soil and rock engineering properties; describe HTRW potential.

Groundwater Conditions

Determine extent and mode of project-induced changes in ground water regime; show predicted changes for aquifers; discuss predicted impact on water supplies and water-sensitive habitats.

Earthquake Analyses

Determine design earthquakes for each site; perform preliminary dynamic analysis; evaluate foundation areas for liquefaction and potential fault movement.

Construction Materials

Locate and describe proposed quarry and borrow sites; prepare detailed geologic maps and sections for each; determine available volumes of material and depths of burden; describe properties and variance of properties; assess commercial sources.

Mineral and Other Resources

Determine location and extent of resources which may be impacted by project.

Project area and site geotechnical conditions developed and defined to extent necessary to select most effective and economical site, to develop reliable cost estimates, and to initiate detailed design studies. Environmental and HTRW conditions are defined and included in impact statements.

Figure 2-4. Schematic diagram on development of site selection investigations, general design memorandum (GDM)

DESIGN INVESTIGATIONS

DATA COLLECTION

Environmental/Ground water

Continue needed ground water data collection; observation well readings, pump tests, etc.; collect geotechnical data needed to update environmental assessments.

Subsurface Explorations

Expand coverage at selected structure sites, excavations, material sources, and relocations; log soil and rock types, structure, and drilling conditions.

Borehole Photography/TV

Obtain fracture frequency, orientation, and aperture; macrotextural and structural features; boring wall conditions.

Borehole Geophysics

Expand coverage with noncore borings; obtain in situ properties and stratigraphic correlation.

Water Pressure and/or Pumping Tests

Obtain permeabilities; monitor water levels.

Material Testing

Complete classification and index testing; perform engineering properties tests; continue and complete special testing started in earlier stages.

Exploratory Excavations and Constructions

Trenches, pits, adits, calyx holes, test quarries and borrows, test fills, test grout panels, etc.; in situ examination; in situ materials properties tests.

Instrumentation

Install and initiate readings on foundation instrumentation (e.g., piezometers, slope indicators) to develop baseline conditions.

DATA ANALYSIS

Ground water Assessment

Continue analyses started in earlier program; finalize statement of project impact on ground water.

Project Site Conditions

Update site geologic maps, geologic sections, soil and rock classifications, rock structure, material hydraulic characteristics, ground water conditions; complete design earthquake, reservoir leakage, and other special studies.

Structure Excavation Site Conditions

Develop detailed distribution of subsurface materials, select pertinent engineering properties for each material; complete dynamic analyses; analyze data and describe encountered conditions from any test excavations, quarries, grout programs, etc.; discuss all conditions affecting design conditions.

Construction Materials

Finalize volume estimates; show distribution of subsurface materials and their properties; analyze and describe results from test fills; finalize assessment of commercial materials sources.

Instrumentation

Reduce data from various sources; correlate data with events occurring; produce baseline plots for construction and postconstruction conditions.

Relocations

Develop pertinent data for each relocation increment in the same manner as structure/excavation sites.

Constructibility

Assure accurate depiction of site conditions and adoption of structures to geotechnical conditions and constraints.

Geotechnical conditions developed in sufficient detail to establish final design and operating requirements for a safe, functional project, develop design details, prepare final cost estimates, prepare plans and specifications, negotiate relocation agreements, acquire necessary lands and complete environmental HTRW assessments.

Figure 2-5. Schematic diagram for design investigations for postsite studies be defined to the extent necessary to design foundation treatment. In the case of water-retention structures, pump and/or pressure tests should be performed. Installation of observation wells and piezometers should be initiated early in the investigations so that seasonal variation in ground water levels can be observed. Geophysical studies should be expanded to include crosshole surveys. Regional ground water and earthquake engineering analyses should be completed. Upon completion of the PED studies, geotechnical conditions should be developed in sufficient detail to establish design and operating requirements for a safe, functional project. If the overall project scope is such that feature design memoranda are not prepared, the geologic and soils information should be sufficient to support the preparation of plans and specifications.

(b) Feature design data collection. Following the PED study, project complexity and size will frequently require separate feature design memoranda on such structures as concrete dams, navigation locks, outlet works, road relocation, and other similar project features. Generally, each special memorandum requires a geotechnical investigation. The investigation is an extension of previous studies but focuses on the area surrounding the structure under study. These studies are expanded by close-order subsurface investigations which may include large-diameter borings, cone penetrometer or standard penetrometer tests, test excavations, fills, and grouting programs, detailed laboratory testing, pile driving and load tests, and any other method of investigations which will resolve issues or problems that came to light during the PED study. Such issues and problems may include detailed evaluation of underseepage, dynamic response, and stability. For major projects requiring large amounts of concrete and/or protection stone, separate feature design memoranda specific to these materials should be prepared. This investigation is started during the initial study period and completed early in the feature design study so that the major structure requiring the materials can be properly designed. At the completion of the FDM studies, all geotechnical features and problems should have been identified and resolved. The final design, incorporating the geological conditions encountered at the sites and identifying the selected geotechnical design parameters, will be complete so that preparation of plans and specifications for construction of the project can proceed.

(3) Design investigations reports. Reporting results of design investigations will be in accordance with the overall reporting requirements contained in ER 1110-2-1150. In many cases, project complexity and size will require that the design investigations be reported in the general design memorandum (GDM) and an orderly series of feature design memoranda (FDM). This information provides the basis for constructibility assessment and formulation of the final design and preparation of the construction plans and specifications.

(a) GDM. The results of all foundation and design investigations performed as part of the project engineering studies will be summarized in the GDM and presented in detail in appendices to that report. The updated regional geology, engineering seismology, hydrogeology, and earthquake engineering studies should be thoroughly documented. As previously stated, if a separate report has not been prepared, the site selection studies should be presented as an appendix to the GDM. If FDM are not prepared, the geologic and soils information in the PED should be sufficient to support the preparation of plans and specifications. Discussions should be augmented by geologic maps and profiles, boring logs, laboratory and geophysical data, and special studies relating to seismology, ground water, and construction materials.

(b) FDM. The geotechnical discussion that will be included in the various FDM which discuss geological aspects of the project should be similar in scope to that presented in the GDM. However, only geotechnical data that clarify the particular intent of the FDM will be used. The discussion will be augmented by the appropriate geologic maps and profiles, boring logs, and laboratory and geophysical data. The design memoranda that are distinctly geotechnical or have geotechnical input of significant importance include:

(i) Site geology.

(ii) Concrete materials or protection stone.

(iii) Embankment and foundation.

(iv) Outlet works.

(v) Spillway.

(vi) Navigation lock.

(vii) Instrumentation and inspection program.

(viii) Initial reservoir filling and surveillance plan.

(ix) Intake structure.

(x) Relocations (roads and bridges).

e. Formulation and evaluation of construction plans and specifications.

(1) Biddability, constructibility, and operability review. Constructibility review is performed in accordance to ER 415-1-11. Constructibility studies evaluate compatibility of design, site, materials, techniques, schedules, and field conditions; sufficiency of details and specifications; and freedom from design errors, omissions, and ambiguities. District offices will coordinate project review by geotechnical, construction, and engineering personnel to improve the constructibility of design. The review process should occur during the development of the draft plans and specifications and, therefore, not be responsible for major changes in foundation and embankment design, instrumentation, or other geotechnically related features which could impact on the project schedule.

(2) Preparation of plans and specifications. Plans and specifications will be prepared in accordance with ER 1110-2-1200. The plans and specifications will contain an accurate depiction of site conditions and will be carefully prepared to eliminate or depict conditions which might delay the work or be grounds for claims. Plans and specifications will contain a thorough graphic presentation of all borings made in the area under contract. All boring locations will be shown. Factual data representing field surveys such as geophysical and hydrological investigations shall be presented in a usable form, preferably a GIS format. Because of the voluminous nature of laboratory data, these data not presented with the borings or tabulated elsewhere must be indicated as available to all prospective contractors. Other data in this category could include mapping data, photographs, and previously published geologic reports and design documents.

(3) Geotechnical design summary report. For some projects where geotechnical considerations are of paramount importance, a geotechnical design summary report may be prepared and included with the bid documents. Disclosure of the design assumptions and interpretations of data in this type of document often serve to clarify intent during the construction of a project.

2-4. Construction Activities

a. Purpose. In some cases, construction activities such as test fills or test excavations are performed to prepare plans and specifications that are compatible with the project design. These plans and specifications are to assure construction quality and document actual construction conditions.

b. Scope of geotechnical activities. Geotechnical activities in support of the construction phase of a project can be divided into three phases: construction management, quality assurance, and compilation of summary reports.

c. Execution of geotechnical construction activities. Guidelines for conducting construction activities are contained in the following Engineering Regulations: ER 415-2-100, ER 1110-2-1200, ER 1110-2-1925, and ER 1180-1-6. Construction activities are summarized in Figure 2-6 and discussed as follows:

(1) Construction management. Construction management and policies are performed in accordance with ER 415-2-100. It is the goal of the Corps of Engineers to construct and deliver a quality product. The key to obtaining this objective is an effective construction management system staffed by an adequate number of trained and competent personnel. Areas of expertise shall be appropriate to the type of construction project under contract and can include, but not be limited to, foundation preparation, rock and soil excavation, embankment and concrete control and emplacement, and grouting.

(a) Claims and modifications. Regardless of the intensity of geological investigations during the preconstruction phase, differing site conditions, claims, and modifications are to be expected on complex projects. Therefore, engineering should provide necessary support to investigate claims and provide design and cost-estimating assistance for any claims and modifications.

(b) Site visits for verification of quality. On all projects, but especially those too small to support a resident geologist or geotechnical engineer, site visits should be made regularly by qualified personnel to verify that conditions match assumptions used in designing the project features and to assist construction personnel on any issues affecting construction. All visits should be well documented (including an extensive photographic and video record) and be included in appropriate summary reports.

(2) Quality assurance and management. Quality assurance, which is the responsibility of the Government, will be performed in accordance with ER 1180-1-6. The geotechnical staff members assigned to the project have the responsibility to monitor, observe, and record all aspects of the construction effort relating to foundations, embankments, cuts, tunnels, and natural construction materials. Figure 2-7 shows in tabulated form some of the particular items requiring quality assurance particular to geotechnically oriented features.

(a) Quality assurance testing will be performed to assure acceptability of the completed work and verify quality control test procedures and results. An onsite laboratory should be required on major projects to perform all soil and concrete testing. During construction, considerable data are assembled by the project geotechnical quality assurance staff. These data consist generally of foundation mapping and treatment features, embankment-backfill performance data, grouting records, material testing data, pile driving records, and instrumentation results. Special treatment and problem areas, often requiring contract modification, should be well documented.

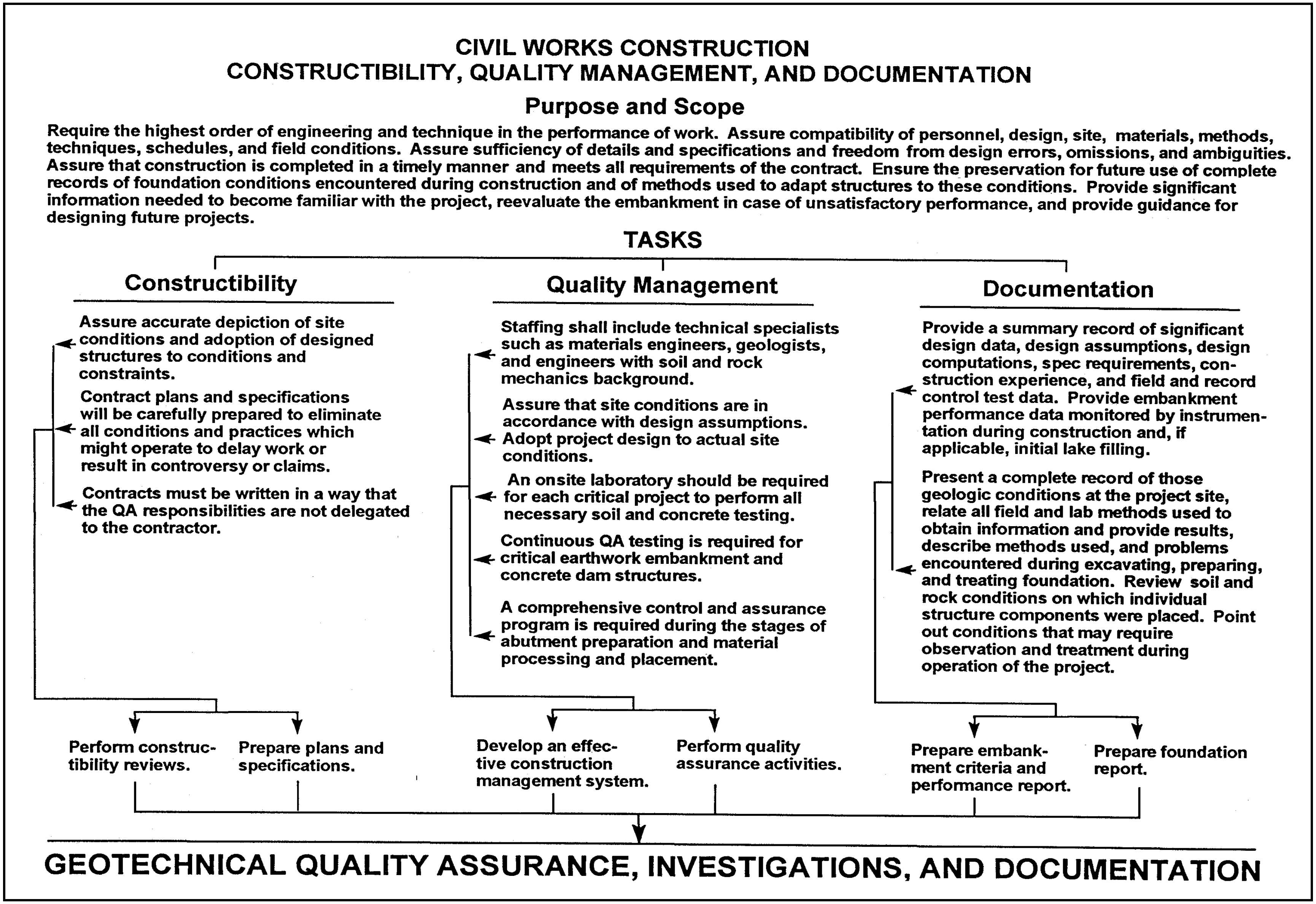

Figure 2-6. Outline of tasks for construction geotechnical activities

CIVIL WORKS CONSTRUCTION
CONSTRUCTIBILITY, QUALITY MANAGEMENT, AND DOCUMENTATION

QUALITY ASSURANCE OF GEOTECHNICAL ACTIVITIES

Excavation Procedures

- Grades
- Unwatering
- Overburden
- Rock
  - Blast patterns/procedures
  - Fragmentation
  - Control of wall rock damage
- Slope stability
- Support
- Preliminary cleanup
- Surface protection

Foundation/Abutment Treatment

- Subsurface
  - Curtain grouting
  - Area grouting
  - Consolidation grouting
  - Caissons, trenches, slurry walls, etc.
- Surface
  - Final cleanup
  - Dental concrete
  - Shotcrete
  - Slurry grouting
- Drainage
  - Adits
  - Drain holes
  - Relief wells

Embankment/Backfill

- Material source
- Material placement
- Control tests
- Slope stability
- Seepage control
- Diversion and closure

Figure 2-7. Critical geotechnical activities that require carefully outlined quality assurance procedures

(b) Early in the construction of the project, the geotechnical staff should develop a data analysis and storage system, preferably one which can be used to monitor construction activities. The Grouting Database Package (Vanadit-Ellis et al. 1995) is a personal computer (PC)-based, menu-driven program that stores and displays hole information, drilling activities, water pressure tests, and field grouting data. Instrumentation Database Package (Woodward-Clyde Consultants 1996) is a menu-driven, PC Windows-based program that can store, retrieve, and graphically present instrumentation data related to construction monitoring. A GIS is an effective and comprehensive means to monitor and analyze all aspects of a construction project, from its development as an idea to postconstruction operations and maintenance. Geotechnical information (data layers) can be a critical part of the data base management and analysis program. A GIS is an organized collection of computer hardware and software, geographic data, and personnel designed to efficiently collect, store, update, manipulate, analyze, and display geographically referenced information.

(c) Figure 2-8 is a flow diagram of the general procedure for carrying out construction investigations and documenting the results. A GIS is specifically designed to compile and analyze spatial data as depicted in Figure 2-8.

(3) Construction foundation and embankment criteria reports.

(a) The purpose of the foundation report is to ensure the preservation for future use of complete records of foundation conditions encountered during construction and methods used to adapt structures to these conditions. The foundation report is an important document for use in evaluating construction claims, planning additional foundation treatment should the need arise, evaluating the cause of foundation or structural feature distress and planning remedial action to prevent failure or partial failure of a structure, planning and design of major rehabilitation or modifications to the structure, providing

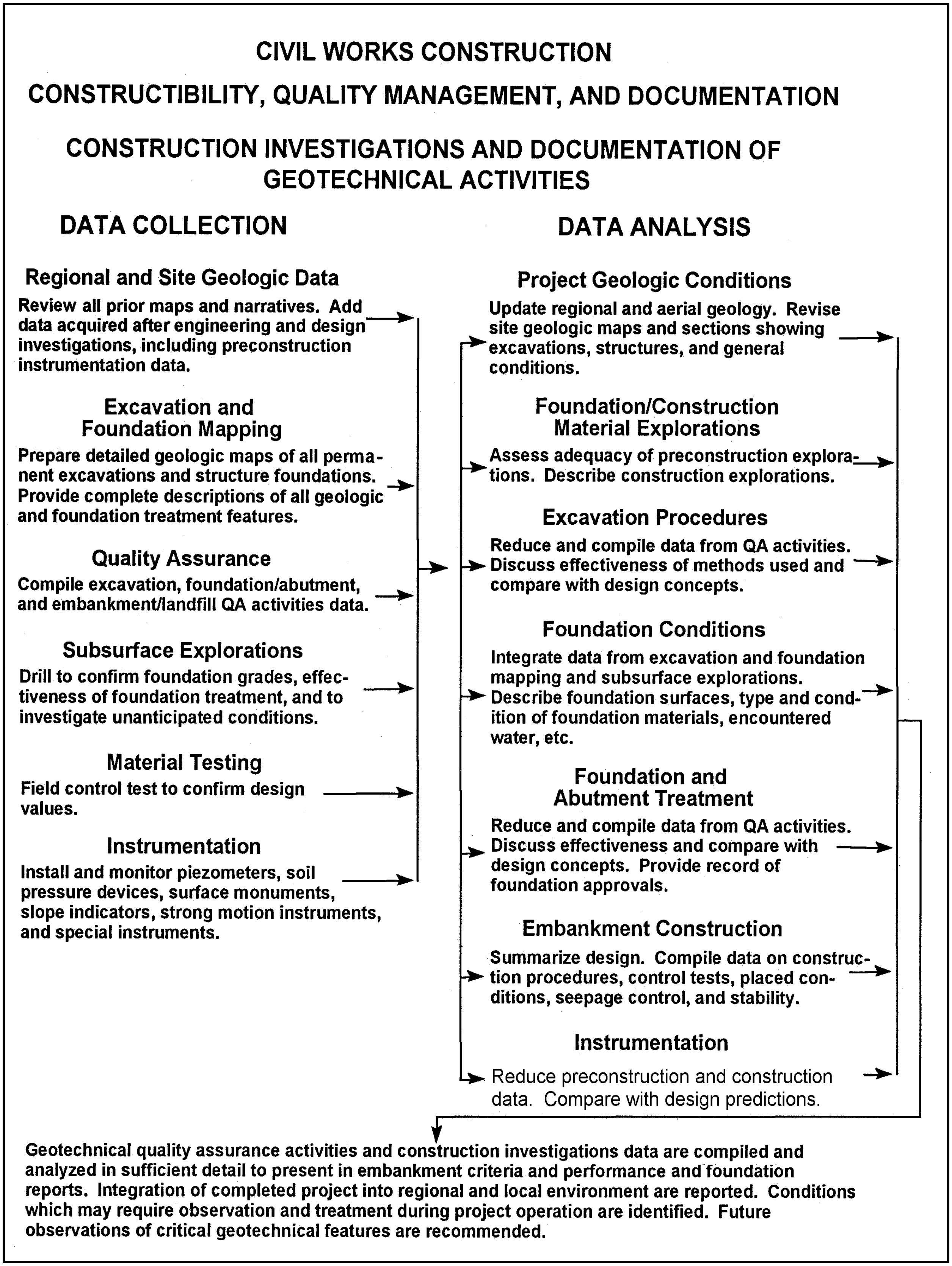

Figure 2-8. Schematic diagram of construction geotechnical investigations and documentation

guidance in planning foundation explorations, and in anticipating foundation problems for future comparable construction projects in similar geologic settings. Site geotechnical personnel responsible for the foundation report must begin to formulate the report as soon as possible after construction begins so that completion of the report can be accomplished by those who participated in the construction effort. This report should include collaboration with design and construction personnel. Detailed video recordings of foundation conditions should be an integral component of the foundation report.

(b) For major embankments, an embankment and performance criteria report will be prepared to provide a summary record of significant design data, design assumptions, design computations, specification requirements, construction equipment and procedures, construction experience, field and record control test data, and embankment performance as monitored by instrumentation during construction and during initial reservoir fillings. The report will provide essential information needed by engineers to familiarize themselves with the project, reevaluate the embankment in the event of unsatisfactory performance, and provide guidance for designing comparable future projects. The report should be authored by persons with firsthand knowledge of the project design and construction. The report should be in preparation during construction and completed as soon as possible following project completion.

Section II
Military Construction Projects

2-5. Background

Program development for Military Construction Army (MCA), Air Force, and other Army projects from initial conception by the installation to final public law appropriation by Congress and construction accomplishment will require a general sequence of geotechnical investigations as shown on Table 2-1. For design phase investigation of facilities required to resist nuclear weapons effects, the guidance in this manual should be supplemented with appropriate material from TM 5-858-3. Information systems to support military construction activities are discussed in ER 1110-3-110.

Table 2-1
Sequence of Geotechnical Investigations with Project Development Stages

Project Development Stages		
Military Construction	**Civil Works**	**Geotechnical Investigations**
Preconstruction and site selection studies	Reconnaissance and feasibility study	Thorough literature search Development of regional geology Field reconnaissances and initial field investigations
Final design studies	Preconstruction planning and engineering General Design Memorandum and Feature Design Memoranda	Review of regional geology Site selection investigations Foundation and design investigations
Construction	Construction	Constructibility review, quality assurance, and postconstruction documentation activities

2-6. Preconcept and Site Selection Studies

a. Purpose and scope. Preconcept information compilation occurs during the guidance year of the MCA program development flow. During the year, the Major Area Commands (MACOM) will prepare annual programs, set priorities, and submit their programs. Initial action consists of preparation of Project Development Brochures (PDB). PDBs contain data necessary to plan, budget, and initiate design of construction projects. The initial PDB is general in nature and provides information regarding project and site conditions. The initial DD Form 1391 contains the preliminary information about the project. A preliminary site survey and subsurface evaluation is included. The preliminary site survey should include a background check to assess the potential for encountering HTRW on potential sites. After approval by the Department of the Army, the second PDB is formulated, generally by the District. This PDB contains total user requirements and complete site and utility support information. Information on general subsurface conditions and any special foundation requirements such as deep foundations or special treatment is included. The preconcept and site selection studies culminate in preconcept control data based on the approved PDB, including a cost estimate and necessary reference data.

b. Scope of geotechnical investigations. Geotechnical investigations during preconcept studies should be performed to a level which assures adequate information. They should be performed by the District's geotechnical element and be sufficiently complete to permit selection of the most favorable site within the regional physical setting, determine the general type of structure best suited to the site conditions, assess the geotechnical aspects of environmental impact, and ascertain the costs of the project. The scope of the investigations should not be greater than that necessary to accomplish these aims. For projects on existing military installations, much of the information needed for preconcept studies is already available and the additional investigation requirements will be minimal. For projects in new areas where information is not readily available, the investigation requirements will be similar to those for Civil Works Feasibility studies. Emphasis, however, will be placed on site-specific parameters relating to size and special requirements for each project.

c. Reporting. Geotechnical investigation results will be reflected in the information and decisions presented in DD Form 1391 and in developed PDBs. Results of drilling and testing programs and special investigations should be compiled in summary reports.

2-7. Concept Studies

a. Purpose and scope. Concept studies provide drawings and data developed prior to initiation of final design, and constitute approximately 35 percent of total design. They serve to define the functional aspects of the facility and provide a firm basis on which the district engineer can substantiate project costs and initiate final design. Included are project site plans, materials and methods of construction, and representative cross sections of structure and foundation conditions. The concept design is accomplished during the design year stage of the program development plan and leads to development of budget data. Budget data reflect firm construction requirements and contain a current working estimate. Data are used in congressional budget hearings.

b. Scope of geotechnical investigations. Geotechnical investigations for concept studies should be performed by the district's geotechnical element and should provide information similar to that included for the preconcept studies but should advance the information to the level required for design and budget development.

c. Reporting. Reporting of the results of the geotechnical investigations is included in the design analysis developed to the 35-percent design study level. Emphasis should be placed on selection of foundation types and the influences of subsurface conditions.

2-8. Final Design Studies

a. Purpose and scope. Final design studies provide a complete set of working drawings for a project, accompanied by appropriate technical specifications, design analyses, and detailed cost estimates covering all architectural, site, and engineering details. These documents are used to obtain construction bids and to serve as construction contract documents.

b. Scope of geotechnical investigations. Geotechnical investigations for final design should be performed by the district's geotechnical element and should provide additional information to the preconcept and concept stage investigations for a final and complete design. All detailed considerations for economic designs, environmental influences, and construction processes should be finalized. The level of information should be similar to that for Civil Works General Design Memorandum studies.

c. Reporting. The results of the geotechnical investigations will be included in the final design analysis. Information should be similar to that collected for Civil Works General Design Memorandum studies, except additional emphasis will be placed on analysis for selection of foundation types and details of the foundation design.

2-9. Construction Activities

a. Scope of geotechnical investigations. In addition to quality control testing, geotechnical activities will be required during construction for special considerations or problems. Such activities will be necessary to confirm design assumptions, analyze changed conditions, determine special treatment requirements, analyze failures, and provide new materials sources.

b. Reporting. Investigation results will be provided in special summary reports and in construction foundation reports as required for major or unique projects.